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Before the
Federal Communications Commission
Washington, DC 20554

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

In the Matter of	)	
	)	
Revision of Part 15 of the Commission's	)	
Rules Regarding Ultra-Wideband	)	Docket No. 98-153
Transmission Systems	)	

REPLY COMMENTS

OF

INTERVAL RESEARCH CORPORATION

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SUMMARY

In light of the overwhelming support of commenters for UWB operations and the numerous potential public interest benefits of UWB devices, Interval Research Corporation urges the Commission to expeditiously proceed with the issuance of a Notice of Proposed Rule Making to modify Part 15 to permit the operation of UWB radio systems.

Although some commenters express concern that UWB devices will cause harmful interference, Interval believes that most of these concerns are due to a lack of familiarity with UWB systems. Accordingly, the Commission should grant experimental authorizations and rule waivers to all applicants. This will enable the Commission to establish a record in the NPRM proceeding on interference issues relating to UWB operations and tailor final rules to assure that harmful interference is not caused by UWB operations.

Interval submits that any interference caused by UWB devices will be no greater than the interference caused by the many unintentional radiators currently operating under Part 15. These radiators operate with the same limits that Interval is proposing for UWB devices and do not disrupt other applications. Thus, applying these limits to UWB systems should adequately protect other spectrum users.

The Commission should permit UWB systems to operate in the TV broadcast and restricted bands because these systems will appear to other spectrum users as nothing more than unintentional radiators, which are currently emitting RF energy into these bands. Due to the number of digital devices that use the radio spectrum, it is unreasonable and unrealistic for spectrum users to refuse to accept emissions in their bands from devices whose emissions resemble emissions from unintentional radiators, and whose operation will not have any cumulative effect. There will be no

unacceptable increase in the background noise level, according to models developed by Interval and others. Therefore, "notching"frequencies is not necessary. Furthermore, such "notching" would eliminate the simplicity of the UWB architecture and would increase the cost of these devices.

Interval urges the Commission to continue its policy of modifying its regulations to accommodate new technologies that promise to provide significant benefits to the public interest. Accordingly, the Commission should adopt of a Notice of Proposed Rule Making in this proceeding, develop a record to allay fears of harmful interference from UWB systems, and promulgate final rules for UWB operations.

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Interval Research Corporation ("Interval")[1], by its attorneys, pursuant to § 1.415(c) of the Commission's rules, hereby submits these Reply Comments in response to the Comments filed in the *Notice of Inquiry* issued in the above-referenced proceeding.[2]

I. INTRODUCTION

The Commission initiated this proceeding to examine ultra-wideband ("UWB") technologies and to consider developing a regulatory structure for UWB transmission systems. Numerous

[1] Interval is a high-technology research laboratory founded in 1992 by Paul Allen and Dr. David E. Liddle. It endeavors to discover or invent technologies that individuals will use in their everyday lives. More than half of its employees are members of the research staff, the majority of whom have advanced degrees. Interval's engineers, computer scientists and other researchers have broad technical expertise related to UWB and communications technologies. For a more detailed description of Interval, see Exhibit 1 to its Comments.

[2] *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, FCC 98-208, Docket No. 98-153. 63 Fed. Reg. 59184 (Sept. 21, 1998), ("*Notice*" or "NOI"). The time for filing Reply Comments was extended to February 3, 1999, *Order Granting Extension of Time*, DA 98-2650, Rel. Dec. 30, 1998.

commenters support Interval's position that this leading-edge technology will encourage a whole new generation of radio frequency ("RF") devices that will serve the public interest[3] and that will not cause harmful interference to any existing applications.[4]

Some commenters raise important issues regarding the lack of comprehensive information about the operation of UWB systems and the possibility that they will interfere with other spectrum users. Interval believes that most of these concerns are due to a lack of familiarity with UWB systems. Furthermore, despite the concerns noted in some of the Comments, Interval and many other commenters believe that the likelihood of significant interference from these devices is remote. Assuming, *arguendo*, the validity of such concerns, the Commission can establish a record on interference issues in a rule making proceeding, and tailor final rules to assure that harmful interference is not caused by UWB operations. The Commission must not let UWB be stifled by sheer speculation that UWB will cause harmful interference. In fact, as demonstrated in Interval's Comments, and in Exhibit 1 attached hereto,[5] any interference caused by UWB devices is not likely to be any greater than the interference presently caused by the many unintentional radiators currently

[3] *See* Interval's Comments at 3-6 for a more complete discussion of UWB's potential applications; *see, also,* TRW Electronics & Technology Division's ("TRW") Comments at 1 ("TRW hopes to use low power UWB technology to enable several new electronic systems in automobiles, primarily in safety systems"); Rosemount Measurement's Comments at 1 (stating that UWB technology can make its radar fluid level gauges more versatile and cost effective); NeoVac's Comments at 1 (arguing that UWB technology could improve the technology and lower the costs of information communication); Pulson Medical, Inc.'s Comments at 2 (UWB technology can "uniquely solve the medical industry's serious communications problems" by "providing reliable medical information to the physician who needs to make rapid, informed decisions [and] to patients who need to be free to live normally but still provide important body function information to the physician and throughout healthcare facilities."); and Low Tech Designs, Inc.'s Comments at 1 (The potential uses of UWB devices "is limited only by the imagination and creativity of the electronics industry." For example, it could "provide the basis for high speed digital local area networks between homes and businesses sharing a common and closely aligned geographic proximity.").

[4] *See, infra*, fn 16.

[5] G. Roberto Aiello, "Analysis of Interference From UWB Transmitters," Interval Research Corporation, January 30, 1999.

operating under Part 15 of the Commission's rules. While UWB operations will add to the existing number of devices that cause noise, there will be no cumulative effect of this noise, and the total amount of noise will not exceed the noise level of unintentional radiators.

As the number of devices that use the radio spectrum multiply and the bands grow more and more crowded, it becomes increasingly necessary for all spectrum users to cooperate with one another in the use of the spectrum and to accommodate new uses of the spectrum where possible. Spectrum users, including those in the TV broadcast and restricted bands, currently are required to accept emissions from unintentional radiators. Experience shows that these emissions do not harm the applications of other spectrum users. Due to the fact that emissions from UWB devices will look like emissions from unintentional radiators, there is no logical reason for UWB devices to be excluded from emitting in these bands. Consequently, it would be unreasonable to prohibit UWB devices from emitting at the same levels as unintentional radiators in any frequency band, restricted or not. Prohibiting such operations would prevent the development and implementation of numerous new devices and technologies serving the public interest, not just UWB.

Based upon the overwhelming support for UWB operations and the likelihood that UWB operations will not cause harmful interference, the Commission should: (i) expeditiously initiate a rule making to implement this new technology; and, (ii) while the rule making is pending, facilitate the compilation of a record in the rule making proceeding through liberal grants of experimental authorizations and rule waivers to all applicants.

II. DEFINITION OF UWB

Interval recommends in its Comments that the Commission adopt the definition of UWB as a signal whose relative bandwidth η is larger than 0.25[6], as expressed in:

$$\eta = 2(f_H - f_L)/(f_H + f_L)$$

where f_H and f_L are the highest and lowest frequencies of interest. Similar definitions are also recommended in several other Comments.[7] For the purpose of measurements, f_H and f_L can be identified at the 20dB attenuation level with instruments currently available in FCC testing facilities. Conventional technology for radar and radio communication are based on the phenomenon of resonance and small relative bandwidth, while UWB systems operate in the range of $0.25<\eta<1$.

Alternate definitions for UWB have been proposed in some of the Comments. For example, Multispectral Solutions, Inc. ("MSSI") introduced "bandlimited short pulses" in the ISM bands[8], and TEM Innovations ("TEM") proposed "wideband low power" (WB-LP) technology, greater than 10MHz.[9] Interval submits that these definitions represent a subset of interesting, but limited, applications that may be of use where cost and the volume are not vitally important, but that are inadequate in the general case because it would require additional electronics to filter the signal within a few percent of bandwidth. Interval urges the Commission not to restrict the possible set of applications for UWB operations by adopting a limiting definition. Rather, the Commission should

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[6] *Assessment of Ultra-Wideband (UWB) Technology*, OSD/DARPA, Ultra-Wideband Radar Review Panel, R-6280, Arlington, VA (1990). *See also, Introduction to Ultra-Wideband Radar Systems*, James Taylor, CRC Press (1995).

[7] *See*, Ultra-Wideband Working Group's Comments at 9; Arthur D. Little, Inc.'s ("ADLI") Comments at 7; XtremeSpectrum, Inc.'s ("XtremeSpectrum") Comments at 6; and Time Domain Corporation's ("Time Domain") Comments at 25.

[8] MSSI's Comments at 16.

[9] TEM's Comments at 7.

encourage the largest possible set of applications by adopting the broader definition of UWB as advocated by several commenters.

III. MEASUREMENTS

In its Comments, Interval argued that the Commission should not use a pulse desensitization correction factor for measuring emissions from a UWB device and should not apply the damped wave prohibition to UWB emissions.[10] Those who commented on these issues agree. For example, the Wireless Information Networks Forum ("WINForum") asserts that pulse desensitization is not relevant to UWB transmitters.[11] TEM also recommends that the Commission refrain from applying pulse desensitization correction on UWB systems.[12] Rosemount Measurement ("Rosemount") argues that using a pulse desensitization correction factor to determine the interference potential of UWB devices will result in values that do not represent their actual interference potential; rather, it "causes a device that has a low potential for interference to look as though it has a high probability to cause interference."[13] Rosemount further asserts that the damped wave prohibition is irrelevant.[14] Lawrence Livermore National Laboratory ("LLNL") also argues that the "pulse desensitization correction factor is not appropriate for measuring emissions from a UWB device" and that the

[10] Interval's Comments at 10-11.

[11] WINForum's Comments at 3.

[12] TEM's Comments at 13.

[13] Rosemount's Comments at 1.

[14] Id. at 8.

damped wave prohibition should not be applied to UWB systems because it does not appear to serve any useful purpose.[15]

Interval encourages the Commission to adopt the same limits and measurement procedures for UWB devices that it currently uses for unintentional radiators, except as noted herein, but suggests that the Commission compile a record, in the context of a rule making proceeding, concerning the interference potential from UWB operations.

IV. INTERFERENCE

Probably the most important issue raised in this proceeding is how much interference, if any, UWB devices will cause to other applications. There is significant support in the various Comments for the position that UWB devices can co-exist with other spectrum users.[16] Interval agrees. As stated in its Comments, Interval submits that numerous unintentional radiators currently operate under Part 15, and the interference they present is similar to the interference that UWB systems

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[15] LLNL's Comments at 8. *See also* Endress + Hauser GmbH & Co.'s Comments ("Endress") at 4 ("It is illogical to apply the pulse desensitization method to UWB pulsed radio systems, because the spectral energy is the critical factor when evaluating the potential for harmful interference."); Arthur D. Little, Inc.'s ("ADLI") Comments at 15 ("Most UWB devices generate pulses which are low in amplitude, very short, and at rates which are high compared with the bandwidths of potential victim receivers. In these cases measured spectra are generally accurate and pulse desensitization of the receiver or the measurement does not occur."); Zircon Corporation's ("Zircon") Comments at 9 (Application of these factors to UWB devices is inappropriate because such application to "very short, high repetition pulses grossly overstates the interference potential of a UWB device."); and Magnetrol International's ("Magnetrol") Comments at 8 ("The prohibition against Class B, damped wave emissions should not be applied to UWB systems.")

[16] *See, e.g.,* LLNL's Comments at 4 (stating that the potential for low power UWB sensors to interfere with other non-Part 15 devices is very low); Magnetrol's Comments at 4 (asserting that the potential for UWB radar devices to interfere with non-Part 15 devices is very low); Professor Robert A. Scholtz ("Scholtz") of the University of Southern California's Comments at 2 (a strong proponent of UWB research, Scholtz believes that, with appropriate constraints on power densities, "this technology is viable for many applications and can coexist with other radio systems."); and TRW's Comments at 1 (TRW is evaluating ways to use UWB technology for automotive safety applications and believes that UWB devices can be operated at power levels such that they will not interfere with any other services).

would cause.[17] These unintentional or incidental radiators, which are operating under the existing limits, do not disrupt other applications. Thus, Interval believes that applying the § 15.109 field strength limits to UWB devices is adequate to protect other users of the spectrum, even those in the restricted bands, because the potential for interference from these devices would be no greater than the interference potential from the millions of Class A and Class B devices currently operating pursuant to Part 15.

Some commenters suggest that the interference caused by UWB devices would be detrimental and substantial. The position of the American Radio Relay League, Inc. ("ARRL") is that interference from radar-type UWB devices may affect TV over-the-air viewers with minimally receptive antennas in residential areas, amateur television communications, and amateur SSB stations operating in various bands, and that interference from communications-type UWB devices will increase substantially if directional antennas are used to permit communications over long distances.[18] In support of its position, ARRL presents a calculation of the interference a Zircon UWB device would provide to a television signal.[19] While Interval is not familiar with Zircon's device, it is Interval's experience that the interference from UWB transmitters is minimally above the spectrum analyzer noise floor and, in fact, has little effect on a television receiver, even one that is located in the same room. In addition, ARRL's assumptions and calculation results for possible interference contain some inaccuracies that render them inapplicable: the high gain transmit antenna

[17] Interval's Comments at 9-10.

[18] ARRL's Comments at 2-3 (note that ARRL recognizes that radar-type UWB devices might operate for only short periods in itinerant locations, and thus might not "present much interference to amateur receivers located at significant distance from the device.")

[19] Id. at 2, fn. 2.

in the example would be very large (more than 10m) and would result in the receiver at 30m being well in the antenna's near field making the interference dependent on the antenna's characteristics. Accordingly, ARRL's allegations of interference are flawed. (*See* Exhibit 1, attached hereto).

Additionally, the U.S. GPS Industry Council ("GPS Council") expresses its concern that interference from UWB devices to GPS operations could impair GPS receiver performance for some applications.[20] Interval is aware of the valuable services provided by GPS commercial and safety-of-life applications and asserts that it is absolutely necessary to ensure that these systems continue to operate safely and provide user satisfaction. However, the large proliferation of unintentional radiators in the market today has made it unrealistic to restrict the operation of devices that emit at the same levels as unintentional radiators in any frequency band, including those allocated to GPS use.

The Comments of the GPS Council fail to consider that GPS operates satisfactorily despite the fact that many unintentional radiators currently radiate on GPS frequencies under Part 15. The interference these Part 15 unintentional radiators present to GPS systems is no greater than the interference UWB systems would cause, nor would the increased noise caused by the presence of UWB devices in the band increase the total noise level because, as noted below, there is no cumulative effect due to the increase in the number of emitters in any band. Therefore, UWB operations should not cause any additional interference problem for GPS operations. Further, spurious emissions, which can be much higher than the proposed limits for UWB transmitters, are allowed in the GPS bands as well. Thus, despite the GPS Council's assertion that public safety

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[20] GPS Council's Comments at 1, 4.

could be compromised because intermittent data may cause a GPS receiver integrated in a complex system to malfunction,[21] it is Interval's assertion that this problem would not be caused by UWB systems operating at the same level as existing unintentional radiators. Such situations should, instead, be addressed by the designers of the complex GPS system through appropriate internal diagnostics.[22]

Interference from unintentional radiators is the primary concern for civil users of GPS, as a result of harmonics, spurious emission, and intermodulation products from other non-GPS transmitters that fall in the GPS band. Several tests and theoretical analysis were performed in recent years to analyze the effect of interference to GPS receivers in the presence of various types of sources, including broadband noise.[23] The interference results depend on both the interference type and the GPS receiver architecture.[24] This is an indication that the GPS community is aware that the proliferation of unintentional radiators creates unavoidable sources of interference, and that the solution to the problem can be found in mitigation techniques for GPS receiver architectures,[25] not in forbidding low level emission in the GPS frequencies. It should be noted that GPS receivers do not work everywhere; they have many blind spots, such as indoors, in a forest, or in an urban setting

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[21] Id. at 5.

[22] However, because no signal can ever be completely removed, UWB devices emitting in the GPS frequencies may very well result in an increase of the noise floor, as happened in the past with unintentional digital devices.

[23] T. Skidmore and F. Liu, "WAAS/LAAS Interference Test Results," in Proc. Inst. Navigation National Tech. Meeting, Santa Monica, CA, Jan. 1997, pp 839-848.

[24] J. Spiker, Jr. and F. Natali, "Interference effects and mitigation techniques," in Global Positioning System: Theory and Application, vol I, B.W. Parkison and S.S. Spilker, Jr., Eds. Washington, DC: American Institute of Aeronautics and Astronautics, 1996, ch. 20, pp. 717-771.

[25] A. Ndili, P. Enge, "Receiver Autonomous Interference Detection," in Proc. Inst. Navigation National Annu. Meeting, Albuquerque, NM, June 1997.

with many tall buildings. Indeed, UWB applications have the potential to complement GPS systems in these situations to provide more accurate information. In the existing literature, most researchers consider TV/FM harmonics, radar devices and mobile satellite service ("MSS") to be the major sources of interference.[26] Interval was unable to find any reference to interference from unintentional radiators, which are similar in spectrum and power levels to UWB transmitters. Interval urges the Commission to adopt, in the context of the UWB rule making, an emission limit for UWB transmitters consistent with the current limits for unintentional radiators already allowed to emit in the restricted bands of operation, such as in the GPS frequencies.

Finally, WINForum's Comments take the position that the FCC should regulate UWB devices in order to prevent or minimize interference that could disrupt operation in the UPCS, ISM and U-NII bands.[27] WINForum's expertise in test and measurement techniques will be very valuable in assisting the Commission to compile a record in the rule making. In the attachment to its Comments, WINForum illustrates that the interference power to a narrowband receiver can vary, in the worst case, as the square of the receiver bandwidth or the transmitted pulse rate, whatever is larger, and that it is proportional to the energy spectral density of a single pulse in all cases. As a consequence, WINForum proposes a test procedure for measuring emissions from UWB devices. Interval proposes an alternative approach to the problem, which is based on the amount of interference caused by a UWB device measured with current regulation for unintentional radiators,

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[26] *See* Id.

[27] WINForum's Comments at 2.

independent of the type of transmitter, as demonstrated in the report attached hereto.[28] This approach simplifies the measurement's procedures protecting an affected victim receiver in an effective way. Nonetheless, WINForum and Interval agree that the power spectral density is the important value, which results in an increase of the receiver's noise floor, and that limiting the power spectral density is the proper way to protect a narrowband receiver because the total interference that affects a receiver does not depend on the peak power or total energy of the pulse, but on the power spectral density within the receiver's bandwidth.

V. TV BROADCAST AND RESTRICTED BANDS

As shown below, many commenters support Interval's position that UWB radio systems should be permitted to operate in the TV broadcast and restricted bands. Interval illustrated in its Comments that UWB systems will appear to other spectrum users to be nothing more than unintentional radiators, which are currently emitting RF energy into these bands.[29] In fact, Interval has previously demonstrated that "laboratory measurements show a striking similarity between UWB transmitters and the emissions from computer boards."[30] Thus, UWB devices should be subject to the same conditions as other Part 15 devices and to the digital device emissions limits that currently apply to AC line conducted emissions.

XtremeSpectrum supports this position, noting that digital systems (including personal computers) unintentionally radiate in a manner very similar to the intentional radiation of UWB

[28] *See* Exhibit 1.

[29] Interval's Comments at 12.

[30] Interval's Comments at 12. *See also* Exhibit 4 to Interval's Comments.

devices.[31] Thus, XtremeSpectrum believes that, at a minimum, UWB devices should also be allowed to intentionally radiate at the Part 15 Class A and Class B limits.[32] Magnetrol advocates modifying Part 15 to remove the distinction between intentional radiation and spurious emissions in the TV broadcast and restricted bands, thereby permitting intentional radiation in all restricted bands, provided that the levels do not exceed those now allowed for spurious emission.[33] Time Domain believes that UWB devices can fit comfortably into existing Part 15 rules, with only some definitions requiring change.[34] Time Domain recommends that UWB transmissions be allowed within the existing emission limits for unintentional digital devices, so that there will be essentially no likelihood of harmful interference to existing systems. Time Domain emphasizes this last point by referring to the fact that there are "literally billions of unlicensed Part 15 devices and an uncountable number of uncontrolled 'incidental' radiators currently in operation."[35] LLNL similarly argues that "Part 15 should be modified so as to remove the distinction between intentional radiation and unintentional/spurious emissions in the restricted and TV bands," and that the radiation level should not exceed those now allowed for spurious radiation.[36] ADLI agrees, recommending that "any new regulatory action [ ] open as many restricted bands as possible to intentional emissions" at levels

[31] XtremeSpectrum's Comments at 6.

[32] Id.

[33] Magnetrol's Comments at 4-5.

[34] Time Domain's Comments at 4-5.

[35] Id. at 4.

[36] LLNL's Comments at 4.

similar to permitted spurious emissions.[37] All of these Comments demonstrate that a growing number of companies involved with UWB believe that these devices will appear to other users as unintentional radiators, and as such should be allowed to operate in the same bands as unintentional radiators.

There have been some suggestions that UWB operations be required to "notch" or eliminate certain frequencies from their operations. Any requirement to prohibit UWB operations in the restricted or other frequency bands would impede the development of UWB technology by eliminating one of its most attractive features -- the simplicity of its architecture. Such a requirement would increase the cost of these devices, which would defeat the purpose of inexpensive UWB systems for consumer applications. A number of commenters agree with this position. For example, LLNL asserts that the use of notch filters would cause excessive ringing in the signal applied to the UWB sensor, thus restricting the applicability of UWB technology.[38] Similarly, Zircon states that notching would severely limit the usefulness of UWB technology.[39] And ADLI argues that prohibiting UWB devices in these bands would cause serious degradation of performance.[40]

Nonetheless, a few commenters were reluctant to allow UWB devices to operate in the TV broadcast and restricted bands. In its Letter submitted in this proceeding, the Federal Aviation Administration ("FAA") expresses its concern for aeronautical safety if these devices are permitted

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[37] ADLI's Comments at 9. *See also*, Endress's Comments at 6 (asserting that these devices should be permitted to operate in restricted bands); Gary Olhoeft, Ph.D.'s Comments at 3 (arguing that the rules should not prohibit operation in TV or restricted bands); and M/A COM's Comments at 1 (supporting the use of UWB devices on an unlicensed basis, including permitting intentional emissions within the restricted bands).

[38] LLNL's Comments at 5.

[39] Zircon's Comments at 8.

[40] ADLI's Comments at 9.

to operate in its bands.[41] Although it is appropriate for the FAA to be cautious towards new services that it suspects may cause harmful interference to its systems, the rules do not forbid unintentional emission or intentional spurious emission in the bands used for aeronautical safety services, as long as the radiators do not exceed the emission limits. Because the emissions of UWB transmitters and unintentional radiators is very similar, as illustrated in Interval's Comments,[42] the effect of a UWB device on the restricted bands will also be very similar.

The FAA further claims that it has "documented cases of radio frequency interference caused to [communications, navigation and surveillance safety] services from non-licensed low power devices such as television antenna amplifiers, baby monitors, personal computers, and UWB operations."[43] The FAA asserts that these incidents caused disruption to air traffic flow.[44] Interval is not aware of significant scientific evidence that proves these anecdotal claims of interference with devices important to the aeronautical radio-navigation system; however, Interval encourages the FAA to include such tests in the record of a rule making on UWB operations, so that it is possible to evaluate how the effect of UWB transmitters compares to other unintentional devices already allowed to operate under Part 15 of the FCC's regulations.[45]

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[41] Letter from Gerald J. Markey, Program Director for Spectrum Policy and Management, Federal Aviation Administration, to Ms. Magalie Roman Salas, Secretary, Federal Communications Commission (Oct. 20, 1998) ("FAA's Letter") at 1-2.

[42] *See* Exhibit 4.

[43] FAA's Letter at 2.

[44] Id.

[45] Interval respectfully disagrees with the FAA's suggestion that UWB manufacturers should demonstrate how radiation from UWB systems could be inhibited or filtered-out in those restricted bands. *See* FAA's Letter at 2. As explained above, not only would it be very difficult to notch out the frequencies reserved to aeronautical safety systems, it would also defeat the purpose of UWB technology by making the receiver design more complex and (continued...)

In addition, the Consumer Electronics Manufacturers Association ("CEMA") and the National Association of Broadcasters ("NAB") jointly filed Comments expressing their concern that the operation of UWB radio systems on an unlicensed basis will cause interference within restricted bands and the TV broadcast bands.[46] They argue that the Commission must not permit UWB operation in these bands until it is absolutely certain that UWB technology will not result in harmful interference within these bands, especially in light of the recent launch of digital television.[47] CEMA and NAB claim that "any interference which impairs DTV reception could significantly delay and hamper the transition to DTV."[48] Interval agrees that UWB devices will emit energy in the TV broadcast bands. However, if that energy is regulated by the current FCC limits for unintentional radiators, then a UWB radiator's effect will not be any different than the effect from existing unintentional radiators. Because the energy from UWB operations is spread across a very large bandwidth, UWB devices do not generate fundamental emission in any specific band, but appear only as noise to a victim receiver. Further, Interval believes that UWB devices will not have a significant impact on digital TV broadcast service due to UWB's low-power emission, which is equivalent to unintentional radiators that are already in use in millions of U.S. households.

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[45] (...continued)
costly.

[46] CEMA/NAB's Comments at 2.

[47] Id. at 3.

[48] Id.

MSSI advocates permitting "bandlimited short pulses" in the ISM bands, while keeping the prohibition in the restricted bands but relaxing the peak-to-average ratio limit.[49] Interval disagrees with MSSI's suggestion to limit the emission to the ISM bands because that would defeat the entire purpose of UWB operations -- not only would it prohibit ultra-wideband operations, but it would also increase the cost of a device operating in the ISM bands to such a point that a number of applications related to safety, medical, education, assistance to the elderly and consumer applications would not be enabled.

Finally, TEM argues that the rules should continue to prohibit operation of UWB systems within the restricted and TV broadcast bands, except for licensed use, due to its assertion that UWB emissions will negatively impact GPS and FAA radar.[50] Nonetheless, TEM recommends that the Commission permit emission in the restricted bands surrounding the ISM bands.[51] Interval vehemently disagrees with this recommendation. Although such Commission action would be sufficient to enable TEM's subclass of applications, it would in fact, prevent the full benefits of UWB operations.

Interval, as supported by many commenters in this proceeding, encourages the Commission to permit UWB devices to operate in all frequency bands, subject to the conditions currently applied to other Part 15 devices and the digital device emissions limits for AC line conducted emissions. Such limitations will protect other spectrum users who currently co-exist successfully with millions of other unintentional radiators.

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[49] MSSI's Comments at 16.

[50] TEM's Comments at 7.

[51] Id. at 7-8.

VI. AGGREGATE EFFECT

In the *Notice*, the Commission expresses its concern regarding the potential for harmful interference due to the cumulative impact of emissions if there is a large proliferation of UWB devices.[52] Interval's position on this important issue is that a large proliferation of UWB devices will ***not*** cause an unacceptably high increase in the background noise level.[53]

Although the FAA alleges that the proliferation of UWB devices will detrimentally affect airline safety,[54] Interval disagrees because there is no aggregation of background noise. As demonstrated in its Comments, Interval researchers have derived a theoretical model that plainly illustrates possible interference problems cannot come from an aggregation of emitters within a 45-degree cone below an aircraft's victim receiver.[55] While an aggregation of transmitters on the horizon potentially causes interference, the smallest amount of attenuation would eliminate any possibility of serious interference.

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[52] *Notice* at 6.

[53] Nonetheless, some commenters fear that a large proliferation of UWB devices will cause substantial interference to other applications. *See* MSSI's Comments at 12 (expressing its concern about the potential for harmful interference due to the cumulative impact from a large proliferation of unfiltered UWB devices, unless there is low cross-correlation between transmitters). However, Interval's Comments describe why, with or without cross-correlation, aggregation is severely limited. Interval's Comments at 8-10. *See also* TEM's Comments at 11 (arguing that a "large proliferation of UWB devices below 5.6 GHz should not be permitted due to GPS and FAA radar vulnerability to interference" but that "above 5.6 GHz environmental absorption will dominate"). Interval does not agree with this position because there is nothing unique at 5.6 GHz bandwidth regarding harmful interference due to cumulative effects. Moreover, environmental absorption exists at all frequencies. The background noise level will not increase unacceptably, as shown above and in Interval's Comments.

[54] *See* FAA Letter at 2 ("Proliferation of UWB systems will result in an increased potential for harmful interference and a concurrent decrease in this agency's ability to safely control the nation's airspace.").

[55] *See* Interval's Comments at Exhibit 3 (W.C. Lynch et al., *An Analysis of Noise Aggregation from Multiple Distributed RF Emitters*, IRC #1998-069).

Furthermore, the long-standing observation of non-aggregation of noise of emitters such as AM and FM radio and cellular systems demonstrates the effectiveness of damping on the possible horizontal aggregation. As explained in Interval's Comments, "[b]oth the theoretical analysis and past experiences with actual, spatially reused radio systems are related to the same theoretical model used for UWB systems and these analyses and experiences strongly indicate that substantial background noise build-up does not, and will not, occur as a result of the operation of a substantial number of UWB devices."[56] Other Comments filed in this proceeding support Interval's position.[57]

In addition, there is scientific evidence that the cumulative effect of interference due to an infinite number of radiators is limited, and that most interference will be generated by the closest radiator, which will <u>never</u> exceed the FCC's limits for unintentional emission. One reason why UWB technology is a source of only low-level interference is that, as the FAA notes,[58] it is difficult to even trace UWB transmitters with conventional direction-finding equipment due to the low power in a specific frequency band.

VII. CONCLUSION

In order to advance this promising new technology and serve the public interest, Interval urges the Commission to initiate a Notice of Proposed Rule Making. To the extent that some unknown implications of UWB operations exist, the Commission can establish a record in the rule

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[56] Interval's Comments at 8.

[57] Anro Engineering, Inc. ("Anro") argues that there is no harm in the proliferation of a large number of these short-range products. Anro's Comments at 5. Similarly, Time Domain argues that the proliferation of UWB devices will not raise the noise floor, noting that the "proof exists in the form of the billions of Part 15 approved digital devices and incidental radiators that already are in operation and which are not causing the noise-floor to rise immeasurably." Time Domain's Comments at 5.

[58] FAA's Letter at 2.

making by gathering and analyzing the requisite data before promulgating final rules. As part of compiling a record in this proceeding, the Commission should adopt a policy of granting experimental authorizations and waivers liberally to all applicants.

In light of the numerous potential benefits of UWB operations, including many possible safety applications, the Commission should not destroy UWB operations based solely upon the unproven allegations of harmful interference. Interval is aware that some commenters fear possible interference from these devices. However, Interval and a number of other commenters have demonstrated theoretically that the interference potential of UWB devices is no greater that the interference of other devices that are currently operating pursuant to Part 15 of the Commission's rules.

It follows then, that because these Part 15 devices are able to co-exist with all other spectrum users, UWB devices should also be able to co-exist. The FCC must continue its long history of adjusting regulations to meet and accommodate new technology when it promises to significantly benefit the public interest. Indeed, the Commission is required to take such action pursuant to its statutory mandate. Accordingly, the Commission should move forward expeditiously and adopt a Notice of Proposed Rule Making in this proceeding, develop a record which will overcome the fears of harmful interference from UWB operations, and promulgate final rules for UWB operations. In the interim, and as part of compiling a record in the rule making proceeding, the Commission should encourage additional experimentation of all types of UWB operations.

Respectfully submitted,

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ITS ATTORNEYS

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EXHIBIT 1

Analysis of Interference From UWB Transmitters

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January 30, 1999

Analysis of Interference from UWB Transmitters.

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Introduction.

UWB transmitters' spectral characteristics are very similar to unintentional radiators, because of their broadband pulsed emission. This paper shows what effects digital devices or UWB transmitters have on the noise floor of various receivers when these transmitters or devices operate according to the current limits for unintentional radiators.

Thermal noise.

The open-circuit rms noise voltage produced by a resistance is:

$$V_N = \sqrt{4kTBR} \tag{1}$$

where k is the Boltzmann's constant ($1.38*10^{-23}$ J/K), T is the temperature in Kelvin, B is the bandwidth in Hertz and R is the resistance in Ohm. The thermal noise is proportional to the square root of the bandwidth and it is present in any circuit element capable of dissipating energy. In a radio system, the bandwidth in equation (1) is not the carrier frequency but the receiver's bandwidth. The available noise power P_n, that is, the maximum power transfer that can occur in a circuit between two resistors equal in value is given by:

$$P_N = kTB[W] \tag{2}$$

The available noise power at room temperature (290K) per Hertz of bandwidth is:

$$P_N = 4 \cdot 10^{-21}[W] = -174[dBm] \tag{3}$$

The thermal noise for a fixed frequency receiver of bandwidth B [Hz] is:

$$P_N = -174dBm + 10\log(B) \tag{4}$$

The noise power in a receiver is in fact larger, because of the contribution of non ideal components to the thermal noise. This contribution can be indicated by the noise figure, expressed in dB. I.e. the noise power present in a 100kHz receiver with 6dB noise figure is:

$$P_N = -174 + 10\log\left(100 \cdot 10^3\right) + 6 = -118dBm \tag{5}$$

FCC limits.

The field strength limits for radiated emissions for class B unintentional radiators according to the current FCC regulation is given in table 1. This limit does not depend on the type of device or the nature of the source, as long as the radiation is unintentional. The limit applies even to receviers operating in the restricted bands of operation.

Frequency of emission (MHz)	Field strength (μV/m)
30-88	100
88-216	150
216-960	200
Above 960	500

Table 1 FCC limits for class B unintentional radiators, measured at a distance of 3m.

The signal strengthavailable at the input of a receiver depends on the type of antenna and its parameters. The power received by an ideal isotropic antenna is given by:

$$P = \frac{E^2}{Z_0}[W] \tag{6}$$

where E is the electric field in V/m and Z_0 is the characteristic impedance of the medium, 377 in air. The received power levels for various frequencies are shown in table 2. These are the maximum power levels that can be generated at a receiver at 3m from an unintentional radiator under the current regulations. These values are a function of the maximum allowed electric field and independent of the nature of the source.

Frequency of emission [MHz]	Maximum power [W]	Maximum power [dBm]
30-88	2.65E-11	-75.76
88-216	5.97E-11	-72.24
216-960	1.06E-10	-69.74
Above 960	6.63E-10	-61.78

Table 2 Maximum power received by an ideal isotropic antenna from a transmitter reaching the present limit for class B unintentional radiators under existing FCC regulations.

The values at table 2 are, of course, ideal because the above analysis doesn't include antenna frequency, polarization, and radiation patterns, and should be only used as a reference to infer what the interference is when real components are used.

Noise floor

The FCC specifies that the measurements to determine the radiated field by an unintentional radiator should be made on 100kHz bandwidth for frequencies below 1,000MHz and on 1MHz bandwidth for frequencies above 1,000MHz. Table 3 shows increases in the noise floor to a receiver with an ideal isotropic antenna. For ease of illustration the receiver's bandwidth is assumed to be 100kHz below 960MHz and 1MHz above 960MHz. The thermal noise, according to equation (4), is respectively –124dBm and –114dBm. This assumes no antenna noise that, depending on frequency, antenna pattern, temperature, and elevation can increase this value by a large amount. The receiver's noise figure is also not computed in the table and of course would increase the level of thermal noise.

The signal captured by the receiver decreases when the receiver is apart from the transmitter. Several parameters contribute to this path loss, including operating frequency, antenna height, distance, and obstructions like foliage, hills, buildings, and walls. The signal's attenuation level due to the path loss is proportional to a power of the distance, as shown by the following expression [1]:

$$\bar{L}(d)[dB] = \bar{L}(d_0)[dB] + 10 \cdot n \cdot \log\left(\frac{d}{d_0}\right) \quad (7)$$

where L(d) is the average path loss in dB at a transmitter-receiver separation d, $L(d_0)$ is the path loss at a reference distance d_0 (3m in this case) and n is the path loss exponent that characterizes how fast the path loss increases with increasing transmitter-receiver distance. In free space n equals 2, whereas indoors or in an environment with shadowing or obstructions the value of n varies, depending upon the operating frequency and the characteristics of the environment. An example of indoor path loss exponent estimation is given in [2] for 5.85GHz transmitters in a residential environment for a value of n equal to 3.5. The effect of distance on the electric field's strength at a receiver is shown in table 3.

Frequency of emission [MHz]	Increase [dB] at 3m	Increase [dB] at 30m (n=2)	Increase [dB] at 30m (n=3.5)
30-88	48.21	28.21	13.21
88-216	51.74	31.74	16.74
216-960	54.23	34.23	19.23
Above 960	52.19	32.19	17.19

Table 3 Maximum noise floor increase at a receiver with an isotropic antenna given by a transmitter reaching the current limit for class B unintentional radiator. The noise floor increase is lower at larger distances and indoors or in an environment with shadowing or obstructions.

This values are still ideal, because they don't include receiver's noise figure and antenna's characteristics. Polarization and antenna patterns very significant effects indoors, where multiple reflections modify the characteristics of the transmitted signal. *This analysis shows, however, that unintentional radiators (or UWB transmitters) do increase the noise floor, but that this increase does not create a very large interference, especially in a real environment.* The modest interference level explains why digital devices in operation today increase the noise floor, but do not cause harmful interference to receivers operating in the same frequency bands.

Effect on different bandwidth receivers.

The previous calculation applies to 100kHz bandwidth receivers below 1,000MHz and 1MHz bandwidth receivers above 1,000MHz. Those are the bandwidths at which the measurement equipment is specified to measure the radiated field, according to the current FCC regulations for unintentional radiators. The interference effect when the receiver bandwidth is larger or smaller than the measurement's bandwidth depends on the type of the source of interference [3,4].

Most UWB technology's proponents consider time modulating the interval between pulses with pseudo-random codes, much like spread spectrum. This has the effect of smoothing the spectrum, eliminating any spectral lines. In this case the interference appears as thermal noise and as a consequence both thermal noise and interference are proportional to the receiver's bandwidth and both narrower and wider frequency receivers present the same increase in noise floor as shown in table 3.

The worst case interference for narrower bandwidth receivers occurs when the source's spectrum presents a well-defined spectral line in the receiver's bandwidth. This spectrum may be generated by a series of pulses of repetition frequency larger than the receiver bandwidth, as shown in [4]. The thermal noise decreases according to equation (4), but the interference remains constant, because the receiver isolates a spectral line that appears like a tone. As a result a 10kHz receiver would experience a 10dB increase in noise floor for frequencies below 1,000MHz and 20dB for frequencies above 1,000MHz, as compared to the values shown in table 3. Such signal, of course, can be generated by digital devices that comply with the current limits today and raise the noise floor in the same way. A solution to this problem, should the FCC consider it necessary to modify the current regulations for unintentional radiators to protect narrower bandwidth receivers by similar sources of interference, would be to define the emission limits not only at 100kHz and 1MHz, but also at lower bandwidths. This change in the rules would guarantee that the noise floor does not increase more than predicted by the test measurements and would more specifically protect narrowband receivers.

The worst case interference for receivers whose bandwidth is much larger than the measurement bandwidth occurs when their bandwidth is also much larger than the distance between spectral lines, as shown in [3]. In this case, the received amplitude is proportional to the receiver's bandwidth and consequently the power is proportional to its square. The thermal noise is still proportional to the receiver's bandwidth, according to equation (4). As a result, the noise floor increase is proportional to the receiver's bandwidth. This calculation implies that, for example, a 10MHz bandwidth receiver experiences a 10dB increase in noise floor for frequencies above 1,000MHz and 20dB for frequencies below 1,000MHz, when compared to the values shown in table 3. However some specific assumptions must be made to achieve this extreme case: the electric field's spectrum must be flat across the receiver bandwidth and all the frequency components must contribute in phase. These assumptions are realistic only when the receiver is specifically designed to take advantage of these characteristics. Generally, such requirements present a challenge to UWB designers: the filter's group delay must be constant over the whole bandwidth of interest, and the antenna's phase center and its transfer function must be constant over the same bandwidth.

Conclusions

It is widely recognized and experimentally proven that current regulations for unintentional radiators are adequate to protect existing services, including restricted bands of operation. Receivers operating in those bands are in fact being designed to minimize interference from unintentional radiators. The actual FCC measurement procedures require measurement of the emission in 100kHz bandwidth for frequencies below 1,000MHz and in 1MHz bandwidth for frequencies above 1,000MHz. The spectrum from most UWB transmitters proposed today is flat, without any spectral lines, and produces interference similar to thermal noise. There is a special case in which receivers with narrower bandwidth than the ones specified in the measurements may be subject to a higher level of noise floor increase than calculated for wider bandwidth receivers. A solution to this problem would be to specify additional measurements at narrower bandwidth to limit the increase in the noise floor. Wider frequency receivers could also be subject to a higher level of noise floor increase. Real filters and antennas generally reduce this problem, because of their non ideal characteristics at very large bandwidth. Special care must be taken by UWB receiver designers to take advantage of the energy emitted over such a wide bandwidth.

References

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[3] J.D.Taylor, Introduction to Ultra-Wideband Radar Systems, Ch. 10, CRC Press, 1995.

[4] WINForum Comments, Attachment 1.